canusa

Newsletter

Canada
United States
Spruce Budworms
Program

NUMBER 22, MAY 1982

Hazard Ratings for the Western Spruce Budworm Developed from Photo Interpretation of Site-Stand Conditions

The synoptic view of the forest provided by remote sensing techniques offers the forest manager a means to monitor large and inaccessible areas in a short time. For many years, aerial observers have plotted moderate and severe budworm defoliation on maps. However, detecting and plotting defoliation damage has been helpful mainly in determining population trends and areas needing control action. Little consideration has been given to identifying factors (e.g., stand, site, and physiographic location) that may render a stand susceptible to future spruce budworm damage.

The study reported here was conducted in the Northwestern United States to identify which independent variables — slope, aspect, percent of host species, elevation, crown diameter, topographic position, and total stand density — are significantly correlated with western spruce budworm defoliation. We selected only those variables that can be measured on existing aerial photographs and maps. If these variables can be related to presence of defoliation and possibly the degree of budworm foliage damage, we can offer the manager a tool to evaluate his forest stands for susceptibility to budworm attack. The manager then has the option to consider alternative silvicultural treatments on these stands in the expectation of reducing future losses. Such an approach has been advocated by forest entomologists and silviculturists for many years.

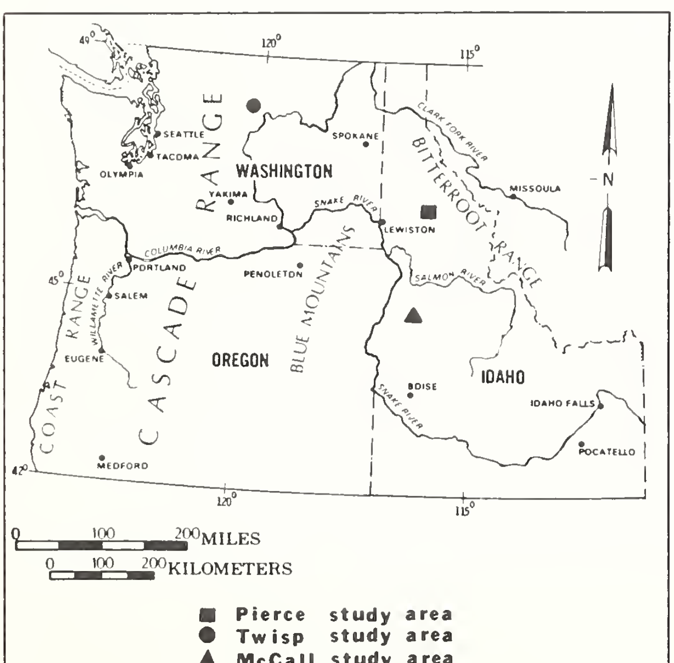

Figure 1. Location of study areas.

The study began in the summer of 1978 and continued through the summer of 1980 on three separate areas having different habitat types (fig. 1). Western hemlock and subalpine fir are primary habitat types occurring in this area. We worked first on the Clearwater National Forest in northern Idaho, which had a long history of budworm damage. However, the year we began the study (1978), the budworm population collapsed.

In 1979, we established plots in Douglas-fir and subalpine fir habitats in north central Washington near Twisp on the Okanogan National Forest, where other CANUSA investigators were working.

Following the decline of that budworm population, we established new plots on the Boise and Payette National Forests near McCall in west central Idaho, where there is a mixture of firs (grand, white, and subalpine), Douglas-fir, and pines (ponderosa and lodgepole) and a continuing and active budworm population.

On all three areas we used a similar sampling design. The areas were selected within boundaries of a known budworm outbreak as plotted on aerial sketch maps the previous year. Size of each study area varied, but total size at each location (Pierce, Twisp, and McCall) was approximately 25 900 ha (100 mi^2). The areas were broken into equal-size strips, 0.8 x 3.2 km (0.5 x 2 mi). Thirty strips were chosen at random from both Pierce and Twisp and 20 for the McCall area (fig. 2). Within each 3.2-km (2-mi) strip, many stand and defoliation conditions existed. At Pierce and Twisp, forest stands were the primary sampling units; at McCall, the randomly located, 0.4-ha (1-acre) plot was the primary sampling unit.

All strips were photographed in a north-south direction at large scale (1:4,000) on color film (Kodak Aerochrome,[1] type 2448) with a 23-cm (9-inch) format camera having a 30.5-cm (12-inch) focal length lens (KA-2). Photos were taken at peak foliage discoloration whenever possible. Unfortunately, at Pierce, both low defoliation and poor flying weather in late July and August prevented photography until late September. The color transparencies were used as a kind of litmus paper, so that trees discolored by defoliation and those not discolored could be associated with site-stand conditions.

We examined a limited number of ground plots selected from each photo strip based upon evidence of defoliation, presence of host tree species, and relative accessibility to ground crews. The location of the ground plots was plotted on the aerial color transparencies for later calibration and referencing during photo interpretation. Both midcrown branch samples and overall tree

[1]Trade names or products are mentioned in this article solely for necessary information. No endorsement by the U.S. Department of Agriculture is implied.

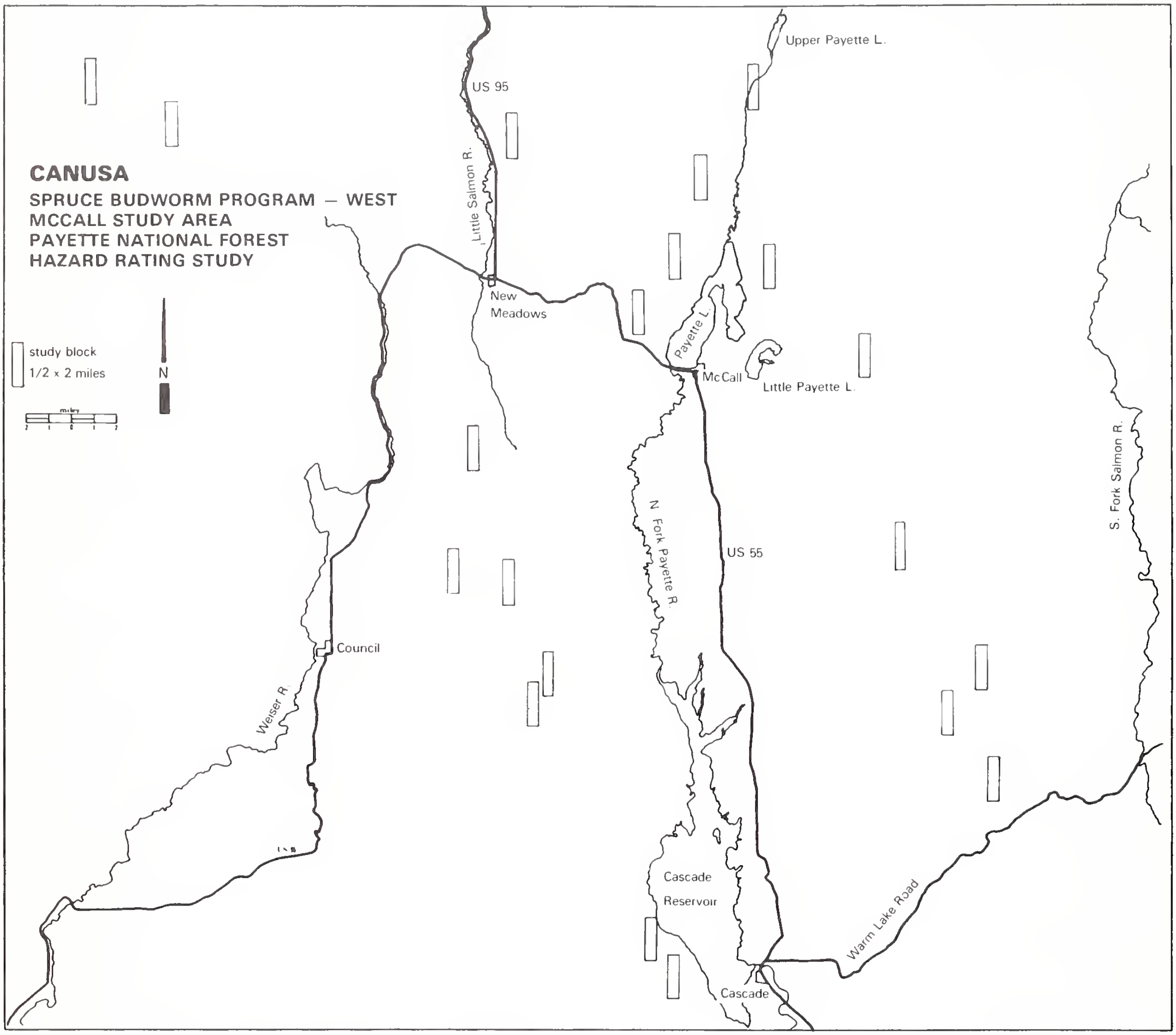

Figure 2. Western spruce budworm outbreak area with aerial photographic sample blocks for McCall, Idaho.

defoliation estimates were made during the ground checks for all dominant and codominant host trees on each 0.4-ha (1-acre) plot. We followed techniques for estimating ground defoliation agreed upon by CANUSA investigators for this study.

We began interpreting photos after the field season using similar interpretation techniques on all three areas. A binocular-equipped Nikon mirror stereoscope with magnification of 1X and 3X was used for stereo viewing of the transparencies.

We did not evaluate plots that had no host type or were presently being logged. On the Pierce area, no defoliation was evident on the aerial photographs because of low budworm populations and the lateness in acquiring the photos. Therefore, we used plot information furnished by Karel Stoszek's crews, who were working on a hazard-rating study using data collected on the ground. For the Twisp area a 10-percent photo sample (0.4-ha [1-acre] plot for every 4-ha [10-acre] stand size) was examined. For the McCall area, a 10-percent random photo sample template (fig. 3) was used (64 plots per strip) on 12 of 20 possible strips. At McCall, 768 photo plots were interpreted (64 x 12 = 768).

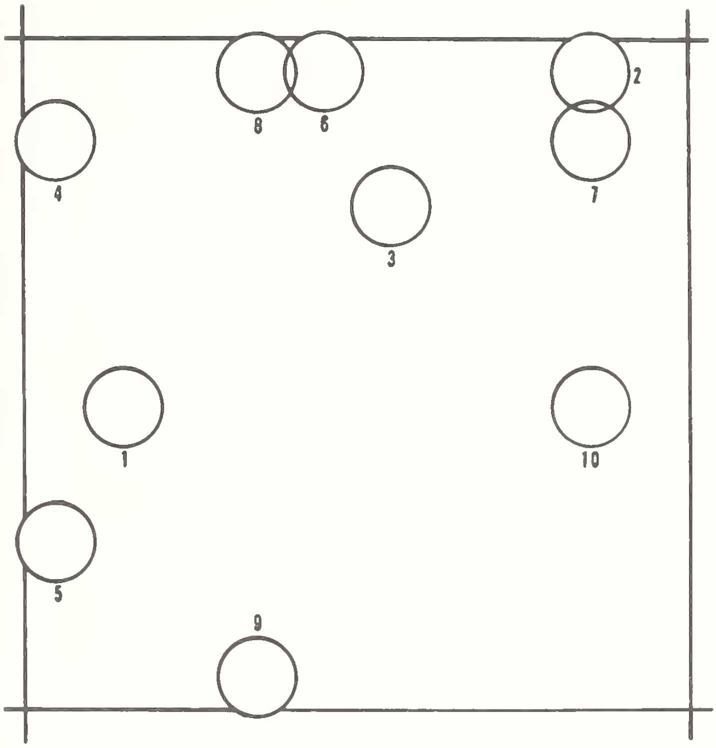

Figure 3. *Ten percent random photo plot template (not to scale) was used to locate plots on alternate aerial photographs. PSR = photo scale reciprocal where scale = 1:4,000.*

Each of the 0.4-ha (1-acre) photo plots was interpreted for the following data:

Independent variables

a. Elevation — to the nearest 3 m (10 ft) from U.S. Geological Survey maps (1:24,000).

b. Slope — into three categories, 0 to 15 percent, 16 to 65 percent and greater than 65 percent. A specially built stereo slope comparator was used to simplify this measurement.

c. Topographic position — ridge, sidehill, or bottom.

d. Aspect — to nearest 22.5° of azimuth.

e. Crown closure — open or closed.

f. Stand levels — single or multistoried.

g. Density — of all tree species in percent of total plot area.

h. Purity — proportion of fir species to all other tree species.

i. COSA and SINA — Cosine of the aspect times tangent of the slope, and sine of the aspect times tangent of the slope: a measure of radiation index. Note that this is only a computer operation since aspect and slope values have already been measured.

j. Crown diameter — measured with a crown diameter template.

Dependent variable

a. Current defoliation — estimated on each 0.4-ha (1-acre) photo plot to the nearest 5 percent. It was relatively easy to distinguish defoliation levels greater than 90 percent, but difficult to place percentage values on defoliation levels ranging from 40 to 85 percent. After initial interpretation and referencing to ground examination, we found that defoliation levels less than 40 to 50 percent were difficult to distinguish even on the 1:4,000 scale photography. Although confidence was lower for defoliation levels below 50 percent, we still estimated percentage values for these low defoliation plots. We also found that there was a distinct tendency to overestimate current defoliation on trees with heavy past defoliation and vice versa for low past defoliation.

Analysis and Results

As mentioned previously, current defoliation was extremely low on the Pierce area in 1978; only 36 plots were available for analysis. Not only did we have a low range of defoliation (none and light) but also too few plots to find significant relationships between defoliation and the 10 independent variables. Nevertheless, we did try using a stepwise multiple regression and also a nonlinear regression technique called RISK. RISK is a computer program, developed by Hamilton, that uses defoliation as a dichotomous dependent variable (defoliated or nondefoliated, 1 or 0). We did get some preliminary indications that elevation, elevation squared, purity, and topographic position were related to defoliation.

Analysis of the 152 stands (600 photo plots) in the Twisp area reaffirmed that 152 samples are inadequate to examine so many independent variables. Again both stepwise regression and all-possible regression (SAS R-square and REX-Fortran 4) techniques were examined as well as the nonlinear RISK technique and the SCREEN program, developed by Hamilton and Wendt. SCREEN helps identify the most significant variables to use in the RISK program. All analyses showed similar tendencies, namely that defoliation was most related to elevation, elevation squared, stand purity, density, and crown diameter. These are very similar to the findings of the previous year on different habitat types. Two RISK models were developed for this primarily Douglas-fir type — one where defoliation was greater than 10 percent and the second where defoliation was greater than 50 percent. A model evaluation program was applied to both models and had encouragingly low chi-square values (lower than table values) and indicated that predicted probabilities of defoliation were close to the actual values.

After being frustrated by both light budworm defoliation and inadequate sample size on the Pierce and Twisp areas, we were delighted to find all levels of defoliation

at McCall. Following statistical consultation, we found we could use the randomly located 0.4-ha (1-acre) plot as our primary sampling unit. This latter factor, because of the large sample size (658 plots), greatly enhances the use of multiple regressions and the nonlinear RISK program to establish significant relations between defoliation and the site-stand variables.

Again, linear regressions similar to ones used on Pierce and Twisp data were applied to 1980 McCall data. An attempt to split the data into two-thirds for model development and one-third for model validation did not work out. Primarily, there was an inadequate number of samples representing a range of elevations in both data sets. The best model included the following independent variables: elevation, elevation squared, topographic position, crown diameter, and purity. However, the best linear regression produced an R-square of 0.25, indicating there is 75 percent of the variation in defoliation not accounted for.

Nonlinear analysis for the McCall data was undertaken again using the SCREEN and RISK programs. The SCREEN program was run using various levels of "no defoliation" categories. Because of the way that defoliation was distributed at McCall, a 20 percent breakoff assured adequate sample size for the nondefoliation class of the dependent variable (defoliation). RISK runs were made on various permutations of variables found significant during screening and also for the best linear models. During the RISK analysis we discovered that the elevation-squared variable quite naturally was highly correlated with elevation and caused problems in calculating regression coefficients. This problem was eliminated by using a squared residual derived by obtaining the mean of all McCall plot elevations, subtracting the individual plot elevation from the mean, and squaring the difference. This resulting independent variable was very significantly related to defoliation.

The overall best RISK model developed included elevation, the square of the difference between elevation and mean elevation, crown diameter, topographic position, and purity. The overall chi-square for the model was 4.89. The predicted defoliation probabilities ranged from 4 to 99 percent — a good range in predictions. For the McCall area, a forest stand around 1829 m (6,000 feet) in elevation, with narrow-crowned trees, on lower slopes and stream bottoms, and a high proportion of host to nonhost trees has a higher probability of being defoliated by western spruce budworm.

Conclusions

Damage caused by the western spruce budworm has a different impact on the forest than that caused by the spruce budworm in the East. Populations of western budworm go up and down over long periods (10 or more years), and tree mortality does not seem to be as great a problem as with its eastern cousin. Of course, growth loss and top killing are caused by both species. The appearance of defoliation both on the ground and from aerial observations or color photographs is complicated because current defoliation occurs on top of 1 or more years of previous defoliation. Because of these factors, the assessment of western spruce budworm defoliation by an aerial method lacks easily definable standards, such as color, lack of foliage, or increasing tree mortality. Tree mortality occurs more commonly in Eastern North America. Finally, when budworm populations build up in an area, they seem to inhabit all possible host trees. Evaluating budworm damage is more complex than evaluating damage from an insect, such as the Douglas-fir tussock moth, *Orgyia pseudotsugata* (McDunnough), whose population is more explosive both in its rise and decline.

Despite the complexities outlined above, our study indicates that western spruce budworm does indeed exhibit site preferences, and we can identify these preferred sites using data obtained through remote sensing techniques.

The linear regression results developed significant models, but those models were too weak to produce an acceptable prediction of defoliation. The nonlinear RISK program, on the other hand, produced significant models and acceptable predicted defoliation values. This is due mainly to the broad-brush approach of using a dichotomous dependent variable. Similar results might be expected using a dichotomous variable in a linear analysis. The RISK models have not been validated; however, plans are underway to start the validation study in 1982.

Hazard-rating models developed from remotely sensed data are not an attempt to explain the biological reasons for site preferences. The models are strictly a reflection of those variables at the macro level. Any number of host/pest interactions can be inferred and quantified to explain the observed variances in western spruce budworm site preference. The forest manager needs to know these specific biological interactions, but he also needs information on a broader scale. A hazard-rating model can fill that information requirement and supply the necessary data to decide, for example, which budworm-infested areas to concentrate on. Hazard-rating models may also be used to interface with other stand-growth and insect-dynamic models.

A hazard-rating model for western spruce budworm can be developed on the broadest scale using only elevation and some cubic or quadratic form of elevation (depending on the area) and the percent of host type for a particular area. At this level it would not be necessary to use a defoliation prediction equation but simply to

assign a hazard class to an area based upon its elevation and percentage of host trees. A more refined model would actually predict a probability of a defoliation event occurring and assign hazard classes to these event probabilities.

A pilot study should be completed for any area (National Forest, State lands, etc.) in which a hazard-rating model is to be developed. The variables that should be included in a pilot study are elevation and both a quadratic and cubic form of elevation, percent of host (purity), crown diameter, stand or plot density, aspect, topographic position, and current defoliation level. All these variables except defoliation and purity can be identified on standard resource-scale aerial photographs or maps. Defoliation and purity are obtainable from large-scale (1:4,000) or larger aerial photography, ground visits, or available timber cruise data.

The results of our study demonstrate that aerial photography and remote sensing techniques can be an effective tool in the isolation of forest stands susceptible to defoliation by the western spruce budworm. The nonlinear regression computer program "RISK" was successfully used to develop a significant defoliation prediction model.

Robert C. Heller — Research Professor Emer.
College of Forestry,
Wildlife and Range Sciences,
University of Idaho,
Moscow, Idaho

Hal N. Anderson — Director, Idaho Image Analysis Facility,
Department of Water Resources,
Statehouse,
Boise, Idaho

Lack of Resistance to Carbaryl in Maine Spruce Budworms

Some members of the general public and some scientists have raised a number of concerns about the large spray projects undertaken to control spruce budworm in the Eastern United States and Canada. One of these concerns is the possible development of resistance to insecticides in heavily sprayed insect populations, a phenomenon that had developed in at least 364 species of insects and mites as of 1976. Most of these species are agricultural and public health pests that are exposed to heavy and repeated applications of chemicals.

A study of resistance to insecticides in Maine spruce budworm populations was among a list of suggested studies forwarded to the Maine Forest Service by a Maine environmental group. We agreed to do the study since the methodology was straightforward and inexpensive, and fitted well into existing research programs.

Carbaryl was the chemical chosen to assay resistance. This insecticide has been used in Maine each year since 1975, and has been applied on most of the acreage sprayed each year except for the first. Our plan was to compare the tolerance to carbaryl of budworm larvae from heavily sprayed sites in Maine with tolerance of larvae from areas that have never been sprayed.

In April 1981, branches of balsam fir containing overwintering budworm larvae were collected at three sites in Maine and at three in New Hampshire. The Maine sites were in Lobster Twp., Comstock Twp., and T12 R9. These sites, having been sprayed four or five times between 1975 and 1980, were the most heavily treated that we could identify. The New Hampshire collections were made in Pittsburg and Clarksville Twps. in the extreme northern part of the State. There has been no budworm spraying in New Hampshire.

The collection sites in New Hampshire are within 32 km (20 mi) of the Maine border; however, adjacent Maine regions have been sprayed little or not at all. Also, budworm populations are generally believed to disperse with the prevailing winds, from west to east. There has been no spraying to the west of the collection site in New Hampshire, and we believe these populations to be typical of the unsprayed condition. However, to be certain that unsprayed populations were represented in the study, we also obtained insects from Ontario, a province near the western edge of the budworm outbreak, and an area that sprays only selected, small parts of its outbreak, e.g., seed orchards and recreation sites. Two groups of branch samples, one balsam fir and one white spruce, were air-shipped to us by Gordon Howse, Head, Forest Insect and Disease Surveys at the Great Lakes Forest Research Centre at Sault Ste. Marie. These samples had been collected in the vicinity of Sault Ste. Marie, from areas never sprayed.

Finally, as an additional budworm stock to test, we used the laboratory strain that we obtain periodically from the Forest Pest Management Institute at Sault Ste. Marie. This laboratory strain can be considered as "semidomesticated" but receives periodical infusions of wild budworm genes from the Sault Ste. Marie area.

It turned out that a few of these collections failed to produce sufficient budworm larvae for our bioassays. We had enough insects in two Maine locations (sprayed) and in two of the New Hampshire locations (unsprayed). The two Ontario field locations had to be combined to produce sufficient insects. In all, we had for the tests larvae from two sprayed sites in Maine and four unsprayed sites (two in New Hampshire, one in Ontario, and the laboratory strain).

In early May, the branches from the field collections were set up to force artificial spring emergence. The branches were attached with string to wooden dowels and suspended within large, cardboard boxes (packaging for domestic refrigerators), at room temperature. With a positive response to light and gravity, the emerging, second-stage larvae climbed the branches and strings and aggregated on the dowels at the top. At hourly intervals, we picked up these larvae, using moistened

artist's paintbrushes, and placed about 20 of them in each of several creamer cups containing artificial laboratory diet. The larvae were then incubated in environmental chambers at suitable temperature and long daylength, until they completed the third stage.

At the beginning of stage four, the larvae were transferred to diet cups, where the artificial diet was "enriched" with varying levels of carbaryl. Concentrations of carbaryl in the diet were 0 (untreated controls), 2, 4, 8, 16, 32, and 64 parts per million. For each budworm collection, 30 to 50 larvae were exposed to each concentration of carbaryl.

Technicians checked all cups daily and counted and removed dead larvae. This continued for 10 days. Mortality data were processed by computer using a program for probit analysis. This type of analysis has been standard for many years for data from bioassays, i.e., where the response of a living organism (mortality of budworms in this case) is related to the strength of a stimulus (concentration of carbaryl).

Through probit analysis, we obtained values for LC_{10}, LC_{50}, and LC_{90}. LC is code for lethal concentration (sometimes called LD for lethal dosage). The subscripts 10, 50, and 90 stand for quantities of carbaryl that kill 10 percent or the most susceptible budworms, 50 percent or the average budworms, and 90 percent or the most resistant budworms of the populations exposed. The LC values that we obtained in the test are presented in table 1 and the graphs of the responses to the dosages, in figure 4. These show that the responses of the several populations of budworms to carbaryl were about the same whether sprayed or unsprayed.

Table 1. LC_{10}, LC_{50}, LC_{90} of carbaryl against fourth-instar spruce budworm larvae from each sampling site

Location	Carbaryl (p/m) LC_{10}	LC_{50}	LC_{90}
Maine 1	15.2	20.6	27.8
Maine 3	16.3	18.8	21.7
New Hampshire 1	11.9	18.7	29.5
New Hampshire 3	12.0	18.6	28.9
Ontario	14.0	16.6	19.7
Lab colony	13.9	20.4	29.9

There is nothing to suggest that sprayed Maine budworm populations are more tolerant to exposure to carbaryl. Statistical analysis of the dose-response curves showed no significant differences.

We are not surprised at finding no evidence of resistance in the budworm. Studies of resistance in an insect species are usually initiated after there have been repeated failures of applications of insecticides. We have not experienced such failures with carbaryl against the budworm.

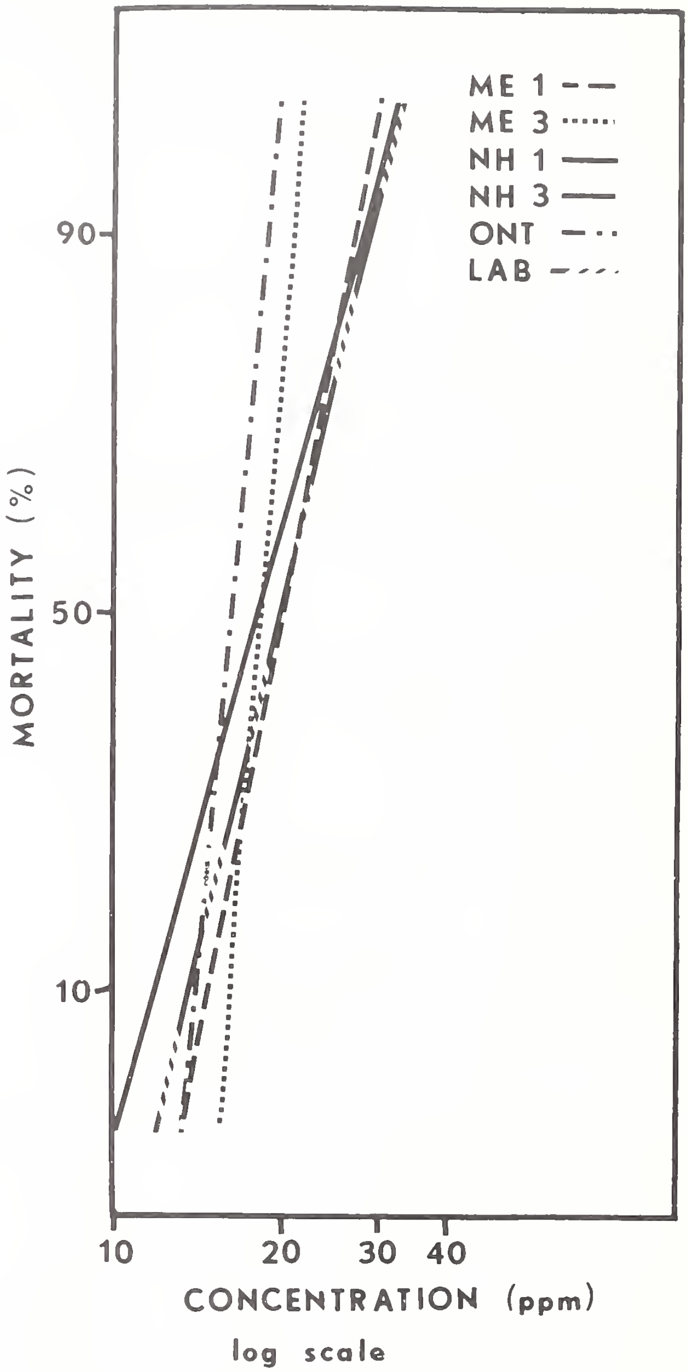

Figure 4. Dose response curves for 4th instar spruce budworm larvae exposed to carbaryl.

An authority on insecticide toxicology and resistance, A.W.A. Brown, now retired from Michigan State University, states that the speed of development of resistance in an insect depends on the intensity of selection (i.e., a strong dosage of insecticide), the number of generations of the insect per year, and the degree of isolation of the population from dilution with surrounding, untreated populations. The budworm

appears a poor candidate to develop resistance on all three criteria. Field dosages of budworm insecticides normally kill 75 to 95 percent of the population, compared to the 98 to 99 percent reductions often achieved in agricultural situations. Budworms have only one generation per year, compared to 3 to 10 generations in house flies, some mosquitoes, and other pests noted for having developed resistance. And sprayed budworms are certainly not isolated from unsprayed populations. Of the 40 million ha (100 million acres) of budworm outbreak in Eastern North America in recent years, we spray less than 10 percent in any year. Also, where spraying is carried out, it is seldom a "blanket" treatment. Spray blocks are broken up with intentional misses (e.g., buffers around water and habitation, nonhost stands, harvested areas) and unintentional skips. It is likely that most budworms surviving the treatments are not truly survivors at all. They didn't survive exposure to the spray but rather avoided it. Survival by this means could not contribute to the development of resistance.

This budworm case can be contrasted with the case of the Colorado potato beetle, where resistance to insecticides has developed in a number of populations. In most regions, the beetle is restricted to potatoes and related crops in commercial or home gardens. There are no wild food plants, and except for those insects in "organic" gardens, all individuals in the population are sprayed heavily and repeatedly each year. Development of resistance is probably inevitable under conditions such as these. Nevertheless, we don't see it as a threat in the case of the budworm.

Charlene D. Madore — Assistant Technologist
Drion G. Boucias — Assistant Professor
John B. Dimond — Professor,
Entomology Department,
University of Maine at Orono

Apparent Resistance to Carbaryl Among Western Spruce Budworm Populations

A toxicological-genetic survey of responses of western spruce budworm populations to carbaryl has been ongoing since 1979. We suspected that populations might exhibit significant, genetically based, differential responses after an investigation of sibling group sensitivity to this chemical indicated a potential for greater than a 50-fold difference in response. Under circumstances in which all but the most tolerant groups were eliminated from a population, resistance seemed to be a definite possibility.

To date, insects from 12 populations collected in five States and a laboratory colony maintained in Berkeley, California, have been tested. Our data are in the process of being subjected to a rigorous statistical analysis in which we will test the significance of relationships between the presence of certain alleles at electrophoretically detectable gene loci and variables such as response to carbaryl, host plant, elevation, and previous spray history in the area. The toxicological results have been fully analyzed and by themselves indicate that resistance to carbaryl is apparently present in certain western spruce budworm populations, and that a wide range of responses exists among the populations tested.

In the toxicological tests, sixth instars were selected from each population. Each bioassay was extensively replicated; as many as 719 individuals were used from a given population. In each replication, Sevin-4-oil® was applied directly in spray form with a laboratory spray chamber. This method permitted realistic estimates of each population's response because carbaryl, the active ingredient of Sevin-4-oil®, acts primarily as a contact poison.

Eight concentrations of Sevin-4-oil® formulated in diesel oil were applied in each replication of an experiment with a single population. Control groups sprayed only with diesel oil were included with each replication. Each experiment was replicated on three to seven separate occasions. Sprayed insects were held with artificial diet for 7 days, at which time technicians determined mortality for each treatment group.

We analyzed the data by probit analysis and made comparisons of relative response at LC_{50}. The slopes (response/unit concentration) for most population response lines were shallow (that is, less than 2.0), a phenomenon typical of chemicals to which resistance has developed or may develop. Table 2 shows these slopes and the range of LC_{50} values observed. The most susceptible population, collected in the Boise National Forest in Idaho in 1981 from an area not sprayed with carbaryl, was about 16 times more susceptible than the most tolerant population — collected from an untreated area of the Beaverhead National Forest in Montana in 1981.

"Resistance" commonly implies that a genetic selection process has occurred as a result of applications of a particular chemical. Observed differences between populations in the same general geographic area, but with different treatment histories, can establish the presence of resistance. Our observations suggest that resistant populations exist in Idaho, Washington, and Montana. Insects collected in 1981 from an untreated area of the Boise National Forest were over four times more susceptible than those collected in an area of the same forest which was sprayed with carbaryl in 1979. In the Okanogan National Forest in Washington, insects collected in 1980 from an area sequentially sprayed with malathion in 1976 and carbaryl in 1977 were almost seven times more tolerant than those collected from an area which had also been treated with fenitrothion in 1975. When insects from the same triple treatment area were tested again in 1981, their response was not significantly different from that observed in 1980, but the LC_{50} observed was 2.3 times less than that for insects in

Table 2. Comparison of responses of 6th-instar western spruce budworm populations to carbaryl (Sevin-4-oil®)

Location	(Year)	Previous Treatment	Slope ± SE	LC_{50} (mg/ml)
Boise NF, ID	(81)	None	1.01 ± 0.37	2.2
Okanogan NF, WA	(81)	Fenitrothion (75), malathion (76), carbaryl (77)	1.30 ± 0.36	2.7
Okanogan NF, WA	(80)	Fenitrothion (75), malathion (76), carbaryl (77)	1.34 ± 0.55	2.8
Boise NF, ID	(80)	None	1.61 ± 0.30	3.9
Okanogan NF, WA	(81)	None	1.82 ± 0.27	6.3
McCall, ID	(81)	None	2.15 ± 0.38	6.4
Berkeley, CA	(79)	None	1.01 ± 0.22	7.8
Carson NF, NM	(81)	None	2.56 ± 0.49	8.5
Coconino County, AZ	(81)	None	1.90 ± 0.26	9.2
Boise NF, ID	(81)	Carbaryl (79)	1.35 ± 0.26	9.4
Beaverhead NF, MT	(81)	Carbaryl (75)	1.72 ± 0.31	15.0
Okanogan NF, WA	(80)	Malathion (76), carbaryl (77)	2.56 ± 0.64	19.4
Beaverhead NF, MT	(81)	None	1.51 ± 0.71	34.5

an untreated area collected in 1981. Finally, western spruce budworm from an untreated area of the Beaverhead National Forest was more than twice as tolerant as budworm from an area of the same forest treated with carbaryl in 1975.

We cannot formulate hypotheses explaining the location of the resistant populations, particularly those in the Okanogan and Beaverhead National Forests, until the statistical analysis relating population genetics to toxicological response is complete. In the interim, we conclude that resistance to carbaryl apparently occurs among western spruce budworm populations.

Jacqueline L. Robertson — Principal Research Entomologist
Pacific Southwest Forest and Range Experiment Station USDA Forest Service Berkeley, California

Molly W. Stock — Associate Professor
Department of Forest Resources
University of Idaho
Moscow, Idaho

Controlling Spruce Budworm on Seed Trees

White and black spruce are major commercial tree species used in reforestation programs in central and eastern Canada. To meet seed requirements in these species, seed production areas and seed orchards are being developed to maximize production of high quality pedigreed seed through intensive stand management. The loss of potential seed crops to the spruce budworm means loss of investment in time and money used to establish and manage seed orchards and seed production areas. Supplies of high-quality seed for regeneration programs are also threatened. In fact, current outbreaks of the spruce budworm are responsible for complete crop failures in certain localities. Because seed use has geographic limitations, localized shortages of seed could restrict the regeneration of commercial spruce forests in eastern Canada.

Historically, chemical control efforts have relied upon aerially applied insecticides to suppress infestations over large areas. Efforts have been aimed at saving timber by foliage protection. Such a control strategy may not be appropriate for high-value trees in seed orchards and seed production areas where a very high degree of control is required to protect flowers and cones. No single control measure is likely to be effective against the spruce budworm in all types of cone crops, and there are risks associated with the use of some effective measures. Thus, the seed production manager should be able to respond to the budworm problem with a choice of several environmentally acceptable and highly effective control measures, including several chemicals and alternative application techniques. The choice of chemicals and application methodology will depend on the type of seed tree to be protected.

A seed production area is a natural stand or plantation of above average quality which is upgraded and thinned by the removal of undesirable trees showing poor growth and form, or signs of excessive damage from insects or fungal diseases. Thinning the stand increases

Figure 5. *A natural stand of white spruce identified and thinned as a seed production area by the Ontario Ministry of Natural Resources, in Reeves Township, Chapleau District.*

cone production and provides easy access for collecting cones by climbing or the use of ladders or other devices to reach cone-bearing portions of the crowns. Thinning the stand and the provision of roadways also facilitates the use of tractor-drawn and fertilizer application equipment.

Plus trees are phenotypically superior trees selected in a seed production area, or elsewhere, for fast growth rate, good form, high specific gravity, freedom from insect and disease damage. Scions or seeds are collected from plus trees for establishment of clonal seed orchards or seedling seed orchards.

A seed orchard is a plantation establishment from selected plus-tree parents for producing genetically improved seed in quantity. Each plus-tree parent is represented throughout the orchard several times, either by grafts, which are identical genetic copies (clones) of the parents, or by seedling progeny, which contain one half the genetic component of the plus-tree parent. Seed orchards are established in localities with favorable climate and soil and, if possible, are isolated to prevent pollination and influx of insects or fungal disease from surrounding forested areas. Seed yields are maximized by management operations, such as fertilizing, irrigating, root pruning, girdling, and pest control.

Kimberly-Clark of Canada Ltd. established the first Ontario seed orchards of black and white spruce at Longlac. Company and Petawawa National Forestry Institute researchers recorded and analyzed productivity for a period of 20 years; results demonstrate that a 1-ha (2.4-acre) orchard will produce close to 1 million seeds on an annual basis. During the course of this study, the orchard was fertilized and mowed to control weeds. Insect problems were apparent and control operations could have doubled or tripled yields.

What pest control options are available for protecting various types of seed trees from spruce budworm? For a large seed production area located on rough terrain with poor access, aerial application of chemical or biological control agents may be the only option available. Reseachers at the Great Lakes Forest Research Centre and the Pest Control Section of the Ontario Ministry of Natural Resources have obtained very high levels of foliage protection of seed production areas with acephate. They do not know yet if levels of protection are high enough to protect flower crops, but certainly, excessive levels of defoliation and tree mortality can be prevented.

For small seed production areas developed from evenly spaced plantations on flat terrain, tractor-drawn or tractor-mounted equipment can be used for applying systemic insecticides with mist blowers or hydraulic sprayers. Foliar applications of systemic insecticides such as acephate, methomyl, and dimethoate will likely provide excellent control of the spruce budworm. Treatments have to be applied very early in the season, before the spruce flowers are in full bloom; treatments during peak flowering will interfere with pollination and reduce seed set.

Small, evenly spaced seed production areas on flat terrain are suitable for soil application of insecticides. Studies to assess carbofuran insecticide as a management tool in white and black spruce seed production

Figure 6. *A white spruce plus tree identified and marked by the Ontario Ministry of Natural Resources.*

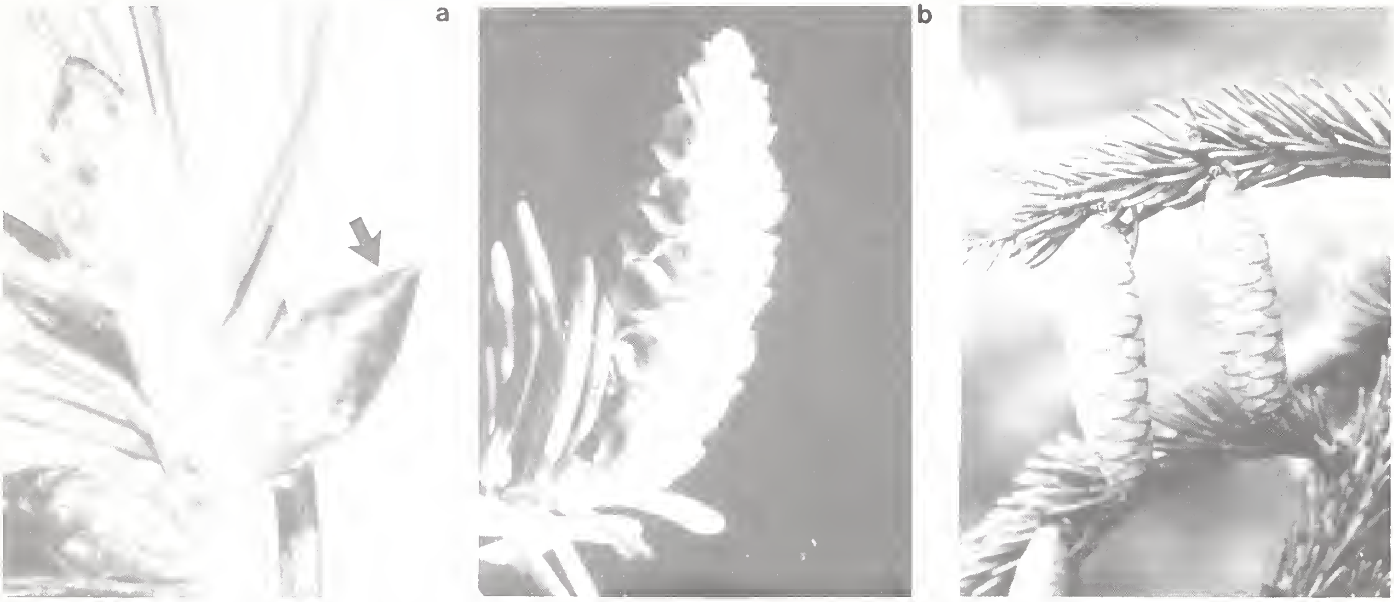

Figure 7. *(a) Female cone bud in early stages of development when spraying or mist-blowing should be done. (b) Female cone bud in full bloom; spraying or mist-blowing at this stage will interfere with pollination and seed set. (c) Female cone bud about 10 days following bloom; scales are closed and pollination is completed. Too late to protect flowers from spruce budworm.*

areas have been conducted by researchers from Petawawa National Forestry Institute (PNFI) in cooperation with foresters at the Bonner Tree Improvement Centre, Ontario Ministry of Natural Resources, Kapuskasing, Ontario. Treatments resulted in complete budworm mortality, provided foliage protection, and induced cone bud initiation. Protective action of the insecticide persisted into the second year following application so that control for at least two seasons may be possible with a single treatment. An apparent phytotoxic effect was noted in treated trees; browning of previous years' needles was the principal symptom. Only a few trees were seriously affected and recovery was evident in the year following treatment. Careful attention must be given to potential problems which carbofuran may pose for wildlife and birds.

Stem implantations of insecticides are used routinely to protect high-value ornamental trees on public or private property. The technique has excellent potential for use on seed trees. In any given year, the number of cone-bearing trees in a seed production area or seed orchard is usually scattered within stands. Thus, stem implantation of single trees is economically and environmentally justified, provided a tree has a large seed crop. There are several methods of implanting chemicals into the stems of trees and premixed injector systems are commercially available from GL (n) Farm and Forest Research Ltd., Oakville, Ontario; J.J. Mauget Co., Burbank, California; or Creative Sales Inc., Fremont, Nebraska. Application of dicrotophos and oxydemetenmethyl provided excellent control of the spruce budworm on white spruce seed trees in 1981 tests at PNFI.

Stem implantation has many important advantages over other methods of insecticide application. The chemicals are premixed, facilitating efficiency and worker safety, and the chemicals are not broadcast in the environment. Units, tools and protective gear to treat a larger number of trees (up to 100 in a single day) can be contained easily in the trunk of an auto. Little space and no additional facilities are required to store the units for the short time between delivery from the

Figure 8. *Applying granular carbofuran to soil with a hoe-drill in a managed spruce seed production area.*

Figure 9. *A white spruce seed tree treated with preloaded injector units for implanting insecticide.*

supplier and application, and used units can be easily packaged for movement to proper disposal sites because of their small size. The method of application is simple and straightforward and can be demonstrated and taught in a matter of minutes.

For more detailed information on aerial applications of insecticides to protect seed production areas contact:
G.M. Howse
Great Lakes Forest Research Centre
Canadian Forestry Service
Environment Canada
Sault Ste. Marie, Ontario

For information on soil application of carbofuran or stem implants of systemic insecticides contact the author of this article.

W.H. Fogal — Research Scientist,
Petawawa National Forestry Institute,
Canadian Forestry Service,
Environment Canada
Chalk River, Ontario

It Can't Be Safe, But It Must Be Acceptable

There is continuing public confrontation today between "science" and "environmentalism." The various arguments are carried on indirectly, with the media acting as the interlocutor between the two parties, who rarely speak directly to one another. Since only the media speak broadly and directly to society, the version of the argument that reaches society is that understood and articulated by the media. In order to make these arguments fit the mandatory time constraints of the media, they are often reduced to such generalities as "the scientist says the procedure is safe" and "the environmentalist says the procedure must not be used until it is proved safe." Neither of these positions is logically tenable. Both generalities state impossible situations. It is hardly surprising there is little evidence of progress in these debates, which cover the range from saccharin to nuclear reactors.

There is no such thing as freedom from risk, or complete safety, in any management action in the natural world. In fact, there cannot be freedom from risk in anything we do. Interference in a dynamic situation without complete understanding of those dynamics will always involve a risk that the forecast result of the interference will be wrong or inadequate. Science will never know all of the dynamics of any natural situation, and consequently there is always risk when society interferes with the dynamics of managing a natural system. Careful scientists, and resource managers, never say there is "no risk" to a procedure, even if the media reported it that way.

To expect that a procedure used in the natural world be demonstrated safe in advance is asking the impossible. If science does not fully comprehend all the dynamics in the natural system, and does not know all of the future external influences, it is simply not possible to state in advance that a procedure is risk free. Indeed, the notion that any procedure can be demonstrated "safe" in advance is itself a dangerous delusion. This would only be possible in situations where knowledge renders the future certain. Perhaps the only certainty in natural systems is that the future is uncertain. Thus, the use of the word safe is inappropriate in these discussions, because it implies that we can achieve a sense of security about the future, which, in reality, we cannot do.

If safe, or zero risk, procedures cannot exist, society must either abandon technology, or deal with two questions: 1) What is the best scientific estimate of the risk involved in using a technology? 2) Is that level of risk acceptable to society? These are two separate questions. Combining them into a single question forces the presumption that the answerer simultaneously represents "best science" and "society." First-rate analyses of this problem of evaluating risk and judging its acceptability can be found in the book by Lowrance entitled "Of Acceptable Risk" and the paper by Clark entitled "Witches, Floods and Wonder Drugs."

An example of an acceptable risk can be seen by examining public reaction to the annual spate of accidents during the hunting season. Records show that lives are lost in hunting activities each year. The risk is not limited to those who take part in hunting because a significant proportion of the fatalities involve nonhunters. The risk to society is demonstrated in lives lost, in injuries that load the health care system, and in reduced enjoyment of the woods by nonhunters during the hunting season. This problem has been the center of much media discussion, yet nowhere does anyone suggest a complete ban on hunting until the risk can be brought to zero, i.e., until it can be proved safe. The public perceives real risk, and acknowledges that

hunting can never be "safe." The public wants the risk reduced (hunter training, etc.) but not for hunting to be eliminated until it can be "proved safe." By whatever means, the public has judged the acknowledged risk from hunting to be acceptable.

The mechanisms by which society decides to accept a risk are not clear, but indeed, risks are recognized and accepted. Lowrance suggests that the process of risk acceptance has several steps. For example, in the case of a new insecticide:

1) A new insecticide is developed in a laboratory and protocols for its use are proposed.
2) The probable risk in the environment from use of the insecticide according to the protocols is evaluated.
3) The acceptability of the risk is judged.
4) If the risk is acceptable, the insecticide is used operationally.
5) The real effects of the insecticide in the environment are measured.
6) The real effects are judged as in step three and the process continues.

There are several interesting features about this process of acceptance. Steps one and two are scientific endeavors, step three is a social endeavor, step four is technological, and step five is quasi-scientific. As a rule, society will not extend credibility to any person, or agency, who carries out two adjacent steps in this process. The laboratory that invents an insecticide is not trusted to evaluate the risk, the agency that applied an insecticide is not trusted to measure the environmental effect, and so forth. This has nothing to do with the capability or trustworthiness of the individuals. The reason is that no sane person would proceed to the next step unless he already believed the technology was ready for that step. Thus, if the same person, or agency, carries out two adjacent steps they are done as one step, and there is no independence of thought.

For either "science" or "environmentalism" to make points with the public, the proponents must be careful not to merge two steps of the acceptance process. The scientist who evaluates a risk and pronounces it acceptable (or otherwise) on behalf of society does not have public credibility, as witness the regular calls for independent reviews. Similarly, the environmentalist who pronounces both an evaluation of risk and a statement of nonacceptability also encounters the same problem.

However society determines acceptability of a risk, it is clear that the steps of risk evaluation and judgment of acceptability must be performed independently in order to achieve public trust. In fact, the public confrontation carried on in the media is precisely an argument between two sides each presuming to do two adjacent steps in the acceptance process. It is thus an argument where neither side has much credibility in the public eye and which confuses the public.

Surveying the mess that surrounds the judgment of acceptability of risk in the use of pesticides, one must conclude that science is not serving society well in terms of risk taking. For reasons of efficiency, fear, or presumptuousness, scientists want to combine invention and risk evaluation, or risk evaluation and judgment. Every time scientists do this, the door is opened for the "other side" to conveniently discredit the work, not on scientific grounds, but on interpretational grounds. This is how the other side makes its best headlines. At the same time science is not being served well by society with respect to risk taking. Many people seem unwilling to take the necessary time and effort to acquire the knowledge they need to play their role. These people seem to welcome the ridiculously simple nostrums that they are told to believe. Blacks and whites are easier to handle than indeterminate grays.

There are some simple steps that science could take to improve the situation. Science, or scientists, should never imply that any procedure is risk free, nor suggest by inference that any procedure can be "safe." Scientists should demonstrate their independence in the risk-taking process, and do one scientific step very well, presenting the information to the next step. Scientists must resist moving with the data to the next step, despite the pressures from the media. Scientists should challenge the procedures of the antiscience lobby rather than directly attacking their conclusions.

G. Baskerville — Assistant Deputy Minister,
Department of Natural Resources,
New Brunswick

References:

Clark, W.C. 1979. Witches, floods, and wonder drugs: historical perspectives on risk management. Proceedings of the Symposium on Societal Risk Assessment: How Safe is Safe Enough? Plenum Press.

Lowrance, W.W. 1976. Of acceptable risk: science and the determination of safety. Kaufman Co.

CANUSA-East Authors Meet

At the end of March, cooperators who have agreed to be chapter authors for the eastern component's management manual met in Broomall, Pennsylvania, to discuss their role and parameters for the book. Janet Searcy joined with Program Management to explain publication procedures, review responsibilities, and discuss scope and tone of the manual.

Program Management will write the introduction and a chapter on the biology of the spruce budworm and its hosts at the tree, stand, and forest levels. Doug Allen has agreed to provide material on budworm detection, and Bart Blum will write about prevention of budworm-caused damage through silvicultural management. Lloyd Irland and John Witter will cover economic impacts of the budworm and damage assessment, respectively. Responsibility for the control section is divided up among

John Dimond (microbial) and Pat Shea (chemical). Joan Trial's section on the environmental impact of control methods will complete that chapter. Gary Simmons's contribution on integrated pest management will conclude the manual.

Like the three "management manuals" being written at CANUSA-West, this book will be a softbound, four-color publication in the USDA Agriculture Handbook series. The audience is users, not policy-makers — forest and pest managers, forest technicians, and knowledgeable landowners. CANUSA-East hopes to publish the book by early 1984.

Feedback on the Bibliography

Fred Knight, director of the School of Forest Resources at the University of Maine at Orono, sent out a questionnaire last January to people receiving the *Spruce Budworms Bibliography* and its supplements. CANUSA must soon decide the future of this bibliographic project, and Fred felt that users should give the Program feedback on it.

Early in March Fred reported the results to Mel McKnight. Of the 101 responders, three-fourths had their own copy of the original bibliography and more than 80 percent found it useful. They did not support the distribution of prepublication computer printouts of the literature data base, however, so these mailings will be dropped.

When preparing a computerized, searchable file of references, management must consider how long the project should be continued. Eighty percent of responders felt the project should go on, with 40 percent favoring indefinite continuation and smaller percentages favoring continuation through the scheduled termination of the Program, through 1985, and through 1988.

One person commented that the original *Bibliography* was hard to read. We have taken steps to improve the quality of reproduction proof generated by the computer we use, and readers should have noted a significant improvement in the appearance of *Supplement 1*.

Supplement 2 is expected to see print by fall of 1982, and we plan to publish a third supplement in 1983. Eventually we hope to combine all three with the original *Bibliography* as a USDA publication in the series "Bibliographies and Literature of Agriculture."

Sue Hacker, who compiles the bibliography at Orono, mentioned that she received from those responding to the questionnaire many new reprints to be included in the data base. This was an unexpected bonus. Program Management encourages all our readers to send one copy of each new publication to Sue at the School of Forest Resources, University of Maine, Orono, ME 04469. American researchers should send a second copy to the appropriate Research Coordinator at Broomall or Portland; Canadian investigators should send their second copy to Chuck Buckner.

Inventory Update

The computer file of the CANUSA Research and Development Management Inventory has been updated. All available progress statements and write-ups on new studies turned in since Issue No. 6 were added. The file now contains information on 226 current and 113 completed studies and projects representing the work of 346 investigators in Canada and the United States.

Distribution of Issue No. 7 was limited due to increasing costs of printing and mailing the Inventory and to the apparent waning interests of CANUSA investigators in its content. However, copies of the Basic Record (total file) and indices to its content are available on request from the Program Managers.

Users' Manual

Program Management for CANUSA East is planning to produce a users' manual tentatively entitled Spruce Budworm-Forest Pest Management Handbook. A meeting was held in Broomall, Pennsylvania on March 30, 1982, to discuss an outline of the manual. There will be a balance of U.S. and Canadian input as authors, coauthors, reviewers, advisors, etc.

In general, all chapter writers must consider the major regional difference in budworm, forest, and population levels. It is assumed that no user will read the book in its entirety, but will refer to the book for specific information. With this in mind, each chapter must stand on its own. Material is to be presented in the simplest, clearest fashion, making full use of tables, graphs, sketches, diagrams, and photographs. The chapters are tentatively titled Introduction, General Biology, Detection, Prevention, Evaluation, Control, and Integrated Pest Management. CANUSA-East Program Management welcomes your comments.

Improving Communication

Producing the *Newsletter* is one of CANUSA's most international ventures. Copy for the American features is collected and edited by Janet Searcy in the Washington Office and then sent electronically to Canada for typesetting, layout, and printing. Jim Mullins edits the Canadian contributions in Ottawa, supervises typesetting and design, and generally shepherds each issue into print.

Recently, Janet and Mel's secretary, Linda Flegel, visited CFS Headquarters in Ottawa to look at production of the *Newsletter*. Discussion was centered on tightening the production schedule and improving communication between the word processors in both offices. Transmission problems that had been encountered between the two machines were worked out by Janet and Linda with Luciana Jovanovic and Diane Sirois, word processor operators in Ottawa. Smooth function of the electronic link between both offices is important not only to the *Newsletter* but is vital to the twice-yearly production of the *Inventory*.

Congratulations David

David Schnieder, the 17-year-old Ottawa high-school student who last year developed a strain of B.t. more virulent against the spruce budworm as a school science project (see *Newsletter* No. 12) has received additional honors for his work. It was announced recently that he has won the top award in North America from the McGraw/Edison Foundation. Schneider, who shared top honors with an Indiana student in the recent Texas competition, will receive a $5,000 grant for further studies and a trip to the 26th annual Edison birthday celebration in Essen, West Germany.

Keep up the good work, David. The CANUSA program extends its congratulations.

Personnel — Hail and Farewell

Hail to Denver P. Burns, new director at the Forest Service's Northeastern Forest Experiment Station in Broomall, Pennsylvania. (CANUSA-East Program Management serves under the Station Director.) Denver comes to the Northeast from St. Paul, Minnesota, where he served as Deputy Director of the North Central Forest Experiment Station for 5 years. Members of CANUSA's Joint Policy and Program Council met him briefly at last August's JPPC meeting, where he introduced local budworm investigators who presented short talks to the Council.

Farewell to Tom Flavell, popular Applications Coordinator for CANUSA-West in Portland. Tom, who has experienced medical problems for some time now, left the Program in February due to ill health. He remains at home, in Beaverton, Oregon, and hopes to do consulting work on a less rigid schedule in the future. Tom will be very much missed as the Program moves toward applications-oriented work, particularly technology transfer.

Russel G. Mitchell, formerly of the Forest Service's Bend, Oregon, silviculture laboratory, has been named to succeed Tom as Applications Coordinator. Russ is a 25-year veteran with the Forest Service. He holds a B.S. in forest management from Oregon State College, an M.S. in forestry entomology from the New York State College of Forestry at Syracuse, and a Ph.D. in entomology from Oregon State University.

Russ is best known for his work on the balsam woolly aphid, and he worked throughout the 1970's on the insect collection committee of the Pacific Northwest Forest and Range Experiment Station. Russ brings to his new position a career's worth of experience in dealing with State and private cooperators managing Oregon's forest, and we are delighted to welcome him aboard.

And farewell to Linda Flegel, Mel's right hand in the Washington Office. Linda has accepted a position with Forest Resources Economics Research in downtown Washington, where she will be an editorial assistant. Her experience with the *Spruce Budworms Bibliography* helped Linda land the new job, which involves preparation of a computerized bibliographic data base.

Items from the Press

Budworm Stopped — A spruce budworm plague that threatened to destroy Newfoundland's forest industries has been stopped, with a 95 per cent reduction of infestation forecast for 1982, says Charles Power, Forest Resources and Lands Minister. Mr. Power told the Legislature the defeat of the insect ends a decade of uncertainty for the 20,000 Newfoundlanders who depend on the forest for a living.

A combination of chemical spray, frost and wet weather in early summer reduced the insect population.

(Chronicle Herald — Dec. 9/81)
Halifax, N.S.

Recent Publications

From the Northeastern Forest Experiment Station, 370 Reed Road, Brommall, PA 19008, you may request a copy of:

Grimble, David G. 1981 "CANUSA mid-program report." U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station, Broomall, Pennsylvania. 13 p.

The following book may be ordered for $11.00 from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402:

Hamel, D.R. 1981. "Forest management chemicals — a guide to use when considering pesticides for forest management." Agric. Handb. 585. U.S. Department of Agriculture, Forest Service, Washington, DC. 512 p. (This book includes EPA-registered uses [formulation, dilution, and application rates] for insecticides available for spruce budworm suppression: acephate, B.t., carbaryl, fenitrothion, malathion, methomyl, naled, and trichlorfon.)

Miscellaneous entries for this issue include one journal article and a book:

Shoemaker, Christine A. 1981. "Applications of dynamic programming and other optimization methods in pest management." IEEE Transactions on Automatic Control, Vol. AC-267, No. 5, October 1981, p. 1125-1132.

Smith, D.B. 1981. "Machinery and factors that affect the application of pathogens." *In:* Microbial control of pests and plant diseases 1970-80. H.D. Burgess, ed. Academic Press. 947 p.

The following reports are available from various CFS locations:

From the Maritimes Forest Research Centre, P.O. Box 4000, College Hill, Fredericton, N.B. E3B 5P7:

Piene, Harald, Dave MacLean, and Ron Wall. 1981. "Effects of spruce budworm-caused defoliation on growth of balsam fir: experimental and design methodology." Information Report M-X-128.

From the Centre de Recherches Forestières des Laurentides, P.O. Box 3800, Ste-Foy, Quebec G1V 4C7:

Blais, R. 1980. "Condition du sapin et de l'épinette blanche dans la région du parc des Laurentides en 1979 face à l'épidémie de la tordeuse et prévision des pertes." Information Report LAU-X-43. This report has an English summary.

From the Northern Forest Research Centre, 5230-122nd St., Edmonton, Alberta T6H 3S5:

Ives, W. 1981. "Environmental factors affecting 21 forest insect defoliators in Manitoba and Saskatchewan, 1945-69." Information Report NOR-X-233. The author refers to the spruce budworm in this report.

From the Forest Pest Management Institute, P.O. Box 490, Sault Ste. Marie, Ontario P6A 5M7:

Retnakaran, A. 1981. "Toxicology and efficacy of insect growth regulators aerially applied against the spruce budworm at Hearst (1978), Wawa (1979) and the French River area (1980)." Information Report FPM-X-45.

Holmes, S.B., R.L. Millikin, and P.D. Kingsbury. 1981. "Environmental effects of a split application of Sevin-2-oil® ." Information Report FPM-X-46.

Morris, O.N., Morgan Hildebrand, and Aubry Moore. 1981. "Comparative effectiveness of three commercial formulations of *Bacillus thuringiensis* for control of the spruce budworm *Choristoneura fumiferana* (Clem.)." Information Report FPM-X-47.

Morris, O.N. 1981. "Report of the 1980 cooperative *Bacillus thuringiensis* (B.t.) spray trials." Information Report FPM-X-48.

Wilson, G.G. 1981. "The potential of *Pleistophora schubergi* in microbial control of forest insects." Information Report FPM-X-49.